COMPACTION UNDER DIFFERENT TILLAGE SYSTEMS IN DRYLAND MEDITERRANEAN SOILS IN CENTRAL SPAIN

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The effects of tillage and machinery traffic on some physical properties and plant development were studied in semi-arid soils from Central Spain where continuous monitoring of the interactive effects of tillage, traffic control and crop rotations are being carried out in long-term experiments.

The results suggested significant differences in the vertical distribution of soil water. The moisture below the plough layer (0–15 cm) remained high under no-tillage conditions whereas, with conventional tillage, the water content was greatest in the surface. These differences in soil moisture were reflected in yield of barley.

The soil compaction indices showed significant differences in conventional tillage or no-tillage conditions, but also depended greatly on the growing season. At sowing, the maximum penetration resistance corresponded to the plots subjected to no-tillage, and did not depend on mechanical effects of machinery traffic. At harvesting, the highest values for soil compaction were found in sampling points affected by wheel traffic in the conventional tillage plots.

INTRODUCTION

Dryland Mediterranean soils subjected to conventional tillage consistently have increased organic matter mineralization, leading to progressive degradation of soil structural, physico-chemical and biological properties. Thus, it has been reported that extensive tillage leads to decreased crop yields (Edwards, 1989; Pimentel *et al.*, 1989; Unger, 1990). Such unfavorable effects may come from compaction of the soil due to traffic of vehicles, as well as from the progressive degradation of soil structure. To avoid these problems, the alternative agricultural systems based upon reduced tillage have been encouraged in semi-arid agrosystems exposed to severe risks of erosion and desertification (Agenbag and Maree, 1991). However, such practices may also lead to increased bulk density and soil compaction (Hamblin and Tennant, 1979; López-Fando and Almendros, 1994) with likely negative effects upon crop yields (Chan *et al.*, 1987).

In addition, soil compaction caused by, for example agricultural traffic, may induce progressive compaction of cultivated soils. This may be exacerbated by low amounts of organic matter and the presence of 2:1 or 1:1 clay minerals (Lal and Stewart, 1990; Mullins *et al.*, 1990).

In this paper we investigate the extent to which some physical properties are damaged by tillage and mechanical compaction in dryland agrosystems in Central Spain.

MATERIAL AND METHODS

Field research was done in the CSIC Experimental Farm located at Toledo (Spain) in 1992–1993. The area has a continental semi-arid climate (range 6 °C–23 °C, as well as 400 mm annual rainfall). The soil type (Calcic Haploxeralf) is representative of so-called "Madrid facies", that occupies large areas of Central Spain. The Ap horizon has a depth of 25–30 cm. The clay, silt and sand content are 16, 22, and 62% (w/w) respectively.

The selected plots had previously been used for long-term experiments of a split-plot design including the main types of tillage practices: conventional tillage (CT) and no-tillage (NT); crop rotations: barley-vetch (B→V), barley-sunflower (B→S) and barley monoculture (B→B). The treatments were carried out in triplicate in 40 × 9 m plots. To study the effect of tractor traffic on soil compaction, a fixed string was placed so that the tractor would always pass through the center of the plot, making a guide between the trafficked and untrafficked areas (Fig. 1).

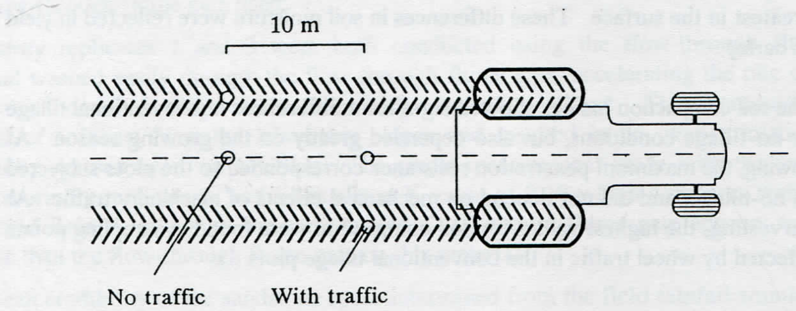

Fig. 1. Scheme of the sampling points to study the effect of wheel traffic on soil compaction.

After plowing, sowing and harvesting, soil samples were taken between 0–45 cm depth at 7.5 cm intervals and the following determinations done for two years. The changes in the water profile during the cropping period were determined gravimetrically at 15-day intervals. The resistance to penetration to a depth of 450 mm was measured with a penetrometer provided with a 1 cm² conical section with 9 replications per treatment, for each application period. Bulk density was estimated in triplicate from soil cores, taken with stainless steel cylinders of 5 cm diameter and 5 cm depth. The crop yield was determined in 1 m² plots.

RESULTS AND DISCUSSION

In general, the penetration resistance tended to be greater under NT than under CT and the values obtained varied significantly during the year (Fig. 2). At sowing, the maximum penetration resistance occurred in the NT plots and was not greatly affected by the machinery traffic. At harvesting, the highest compaction was found in points affected by wheel traffic in the CT plots (ca. 4 MPa). Since compaction would be expected to decreaase root penetration and crop nutrient uptake, the decreased number of macropores under CT may

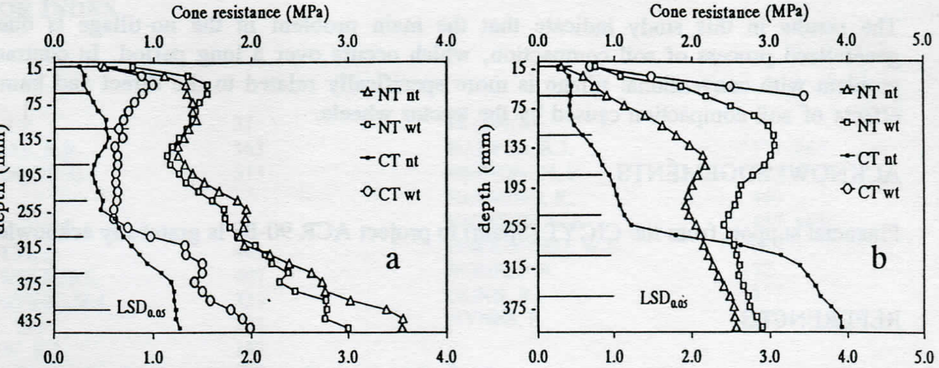

Fig. 2. Cone resistance index in soils at different culture stages: a= barley after sowing, b= sunflower at harvest, NT= no-tillage, CT= conventional tillage, nt= no traffic, wt: wheel traffic.

also be a factor causing reduced yields of barley (Table 1).

The differences in the soil water profiles included: the soil moisture in the upper 15 cm of the NT plots was lower than in CT, whereas in the underlying horizons, water content was higher in the NT plots, especially between 22.5–30 cm. In this situation, the wheel traffic had some positive effects in preventing high evaporative losses. The higher soil water content below 15 cm could be due to compacted layers that held the water tightly in small pores. In years where soil moisture is sufficient for seeding summer crops, NT may be an aid to moisture conservation, which would support the crop during the dry months of Spanish summers.

Table 1. Soil bulk density and crop yield of soils subjected to no-tillage and conventional tillage.

	No-tillage		Conventional tillage		
	with traffic	without traffic	with traffic	without traffic	LSD $P<0.05$
0 – 7.5 cm	1.54	1.48	1.45	1.37	0.08
7.5 – 15 cm	1.54	1.59	1.61	1.52	0.08
15 – 22.5 cm	1.57	1.49	1.61	1.58	0.04
22.5 – 30 cm	1.47	1.43	1.57	1.42	0.06
Mean barley grain yield g m^2	333	336	270	320	23.3

The bulk densities in the 0–15cm layers tended to be lower in CT than in NT treatments. The effect of machinery traffic was more marked in the former case (Table 1). The above differences were much more conspicuous when reflected by the cone index (penetrometer) measurements (Fig. 2).

CONCLUSION

The results in this study indicate that the main problem in the no-tillage is due to a generalized process of soil compaction, which occurs over a long period. In contrast, the problem with conventional tillage is more specifically related to the direct and immediate effects of soil compaction caused by the tractor wheels.

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